

# Optical Fiber Systems for the BigBOSS Instrument

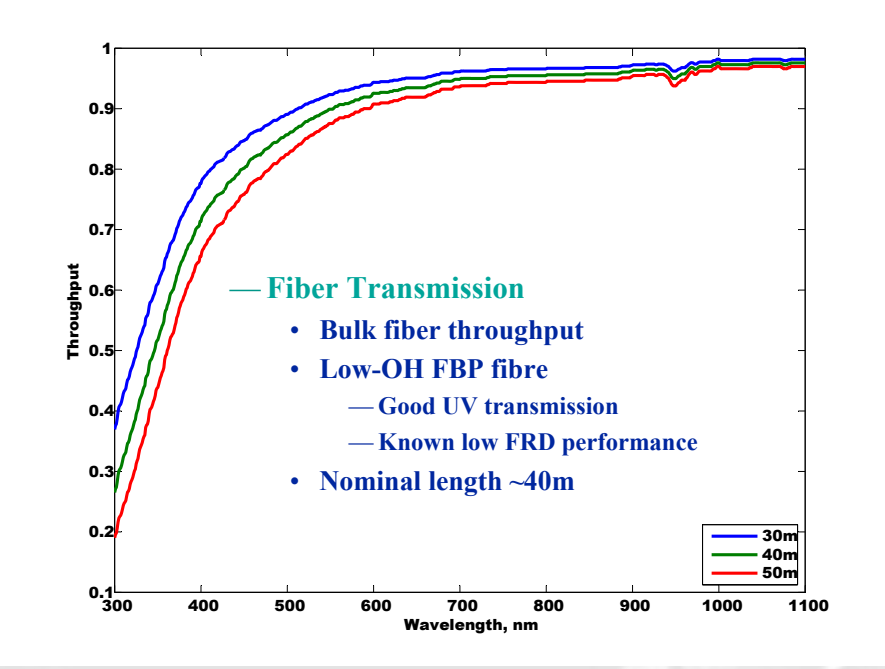
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BigBOSS is a proposed ground-based dark energy experiment designed to study baryon acoustic oscillations (BAO) and the growth of large scale structure through a 14,000 square degree survey of galaxies and QSOs<sup>a,b,c</sup>.

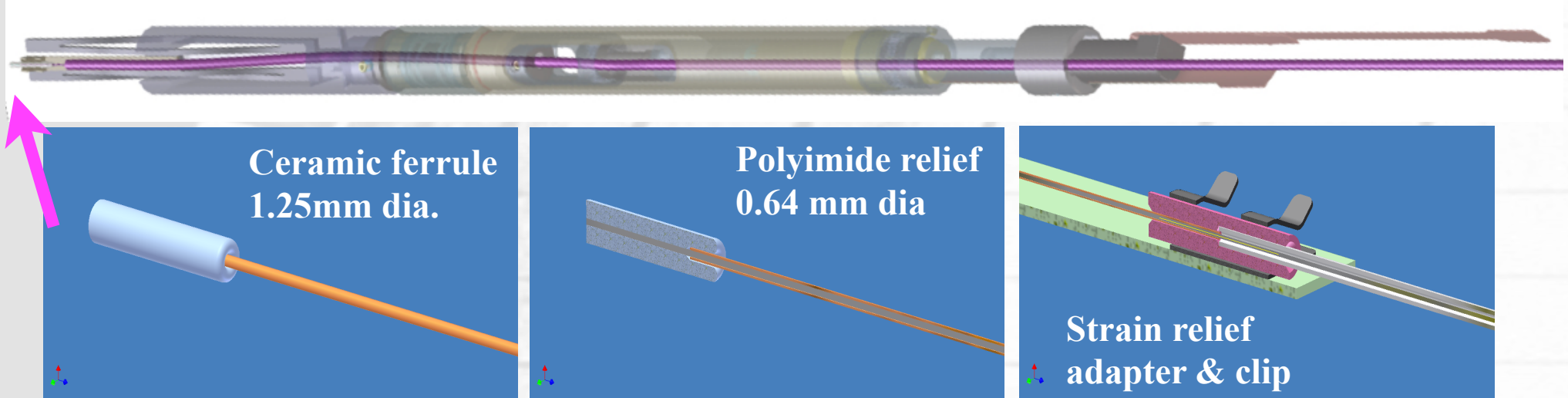
## Fiber



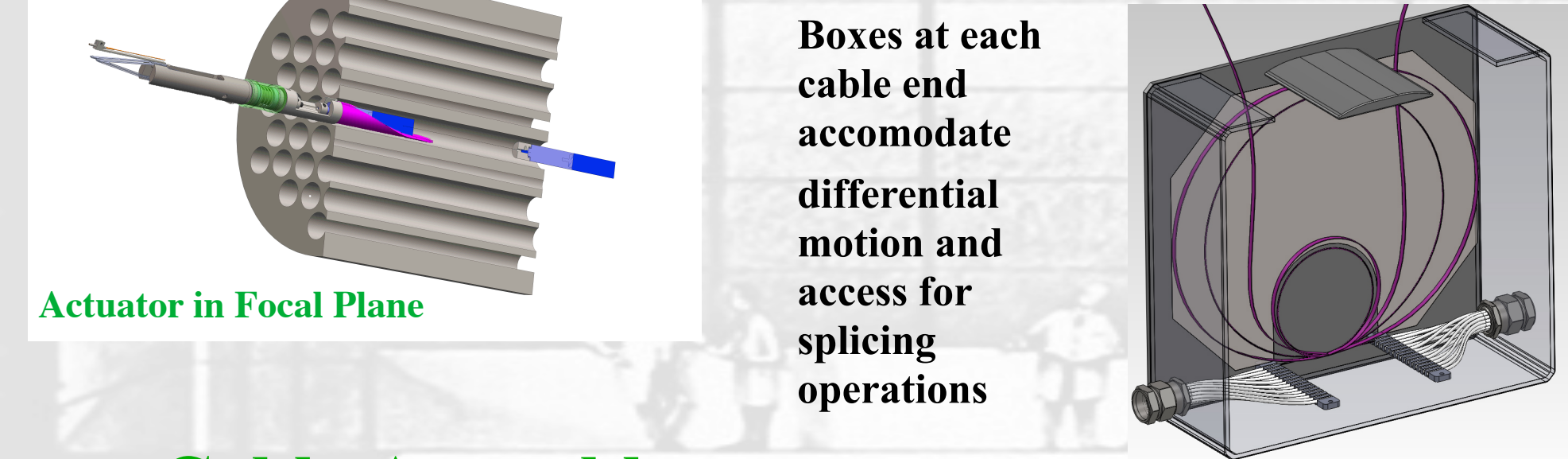
## Fiber System Requirements

- Fiber core: 120µm
- Optical Input: f/4.5, < 0.5 deg telecentricity
- Wavelength range: 360 - 980 nm
- Fiber System Throughput: 90% × fiber bulk × AR
- Input interface: Fiber actuator, motion compatible
- Output interface: Spectrograph compatible
  - Match curved focal surface & f/4.0 output pupil
- In-line connections:
  - Provide for component installation & test
  - Facilitate project fabrication & integration flow

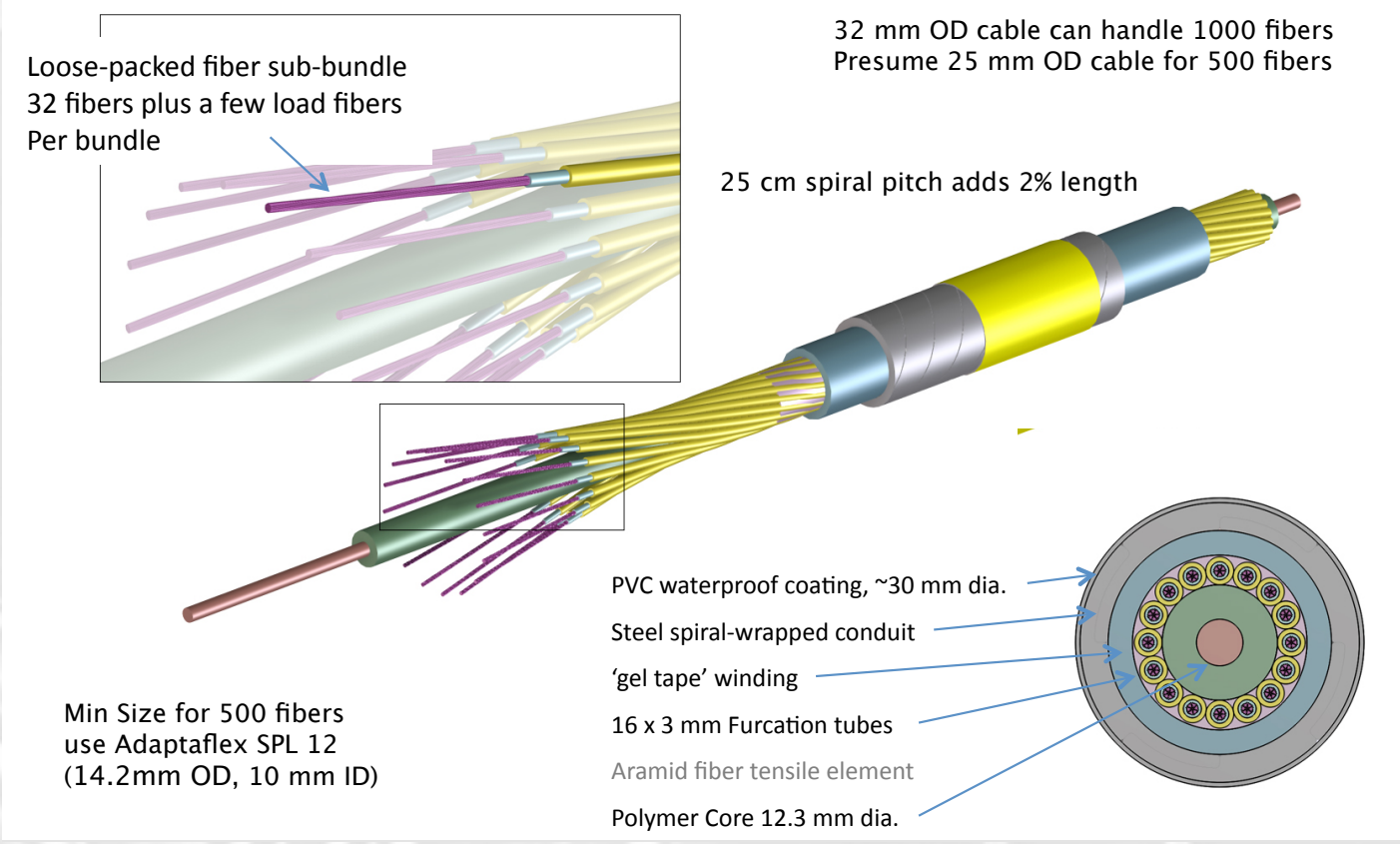
## Ferrule



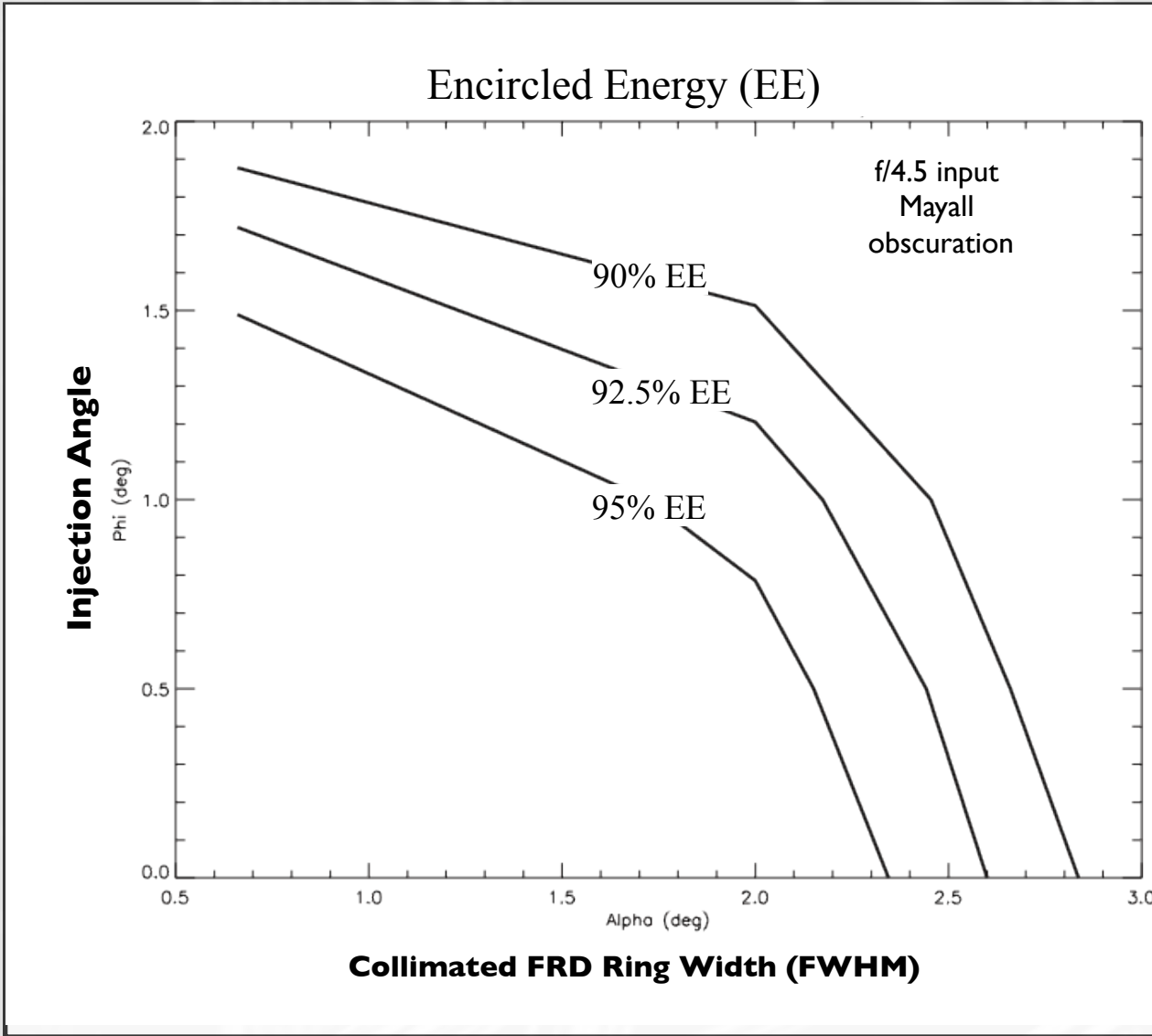
## Connection & Relief Box



## Cable Assembly



## FRD REQUIREMENTS



Intrinsic FRD allowance (numerical simulation) includes both inherent fiber and connection FRD as well as injection angle error (telecentricity)

We budget 1.0° of injection error for the corrector, actuator & fiber mounting

## Standard Fiber Testing

### Quality Standard Fibers

#### Manufacturers Consistency

48 fibers 1m long measured in sequence  
10 fibers subset measured in sequence  
5 fibers subset measured in sequence

C-Tech metal SMA polished

Fibers	FRD°	sigma
48	1.11	0.21
10	1.23	0.22
5	1.37	0.31

3 trials

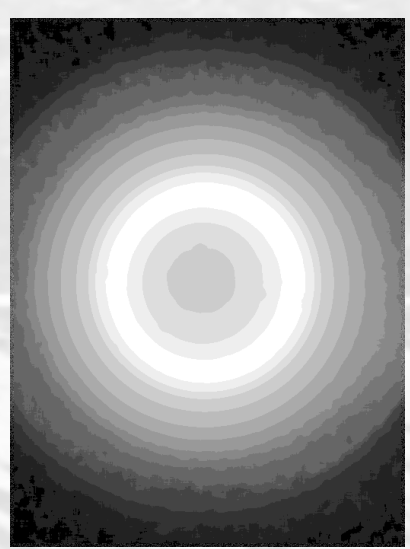
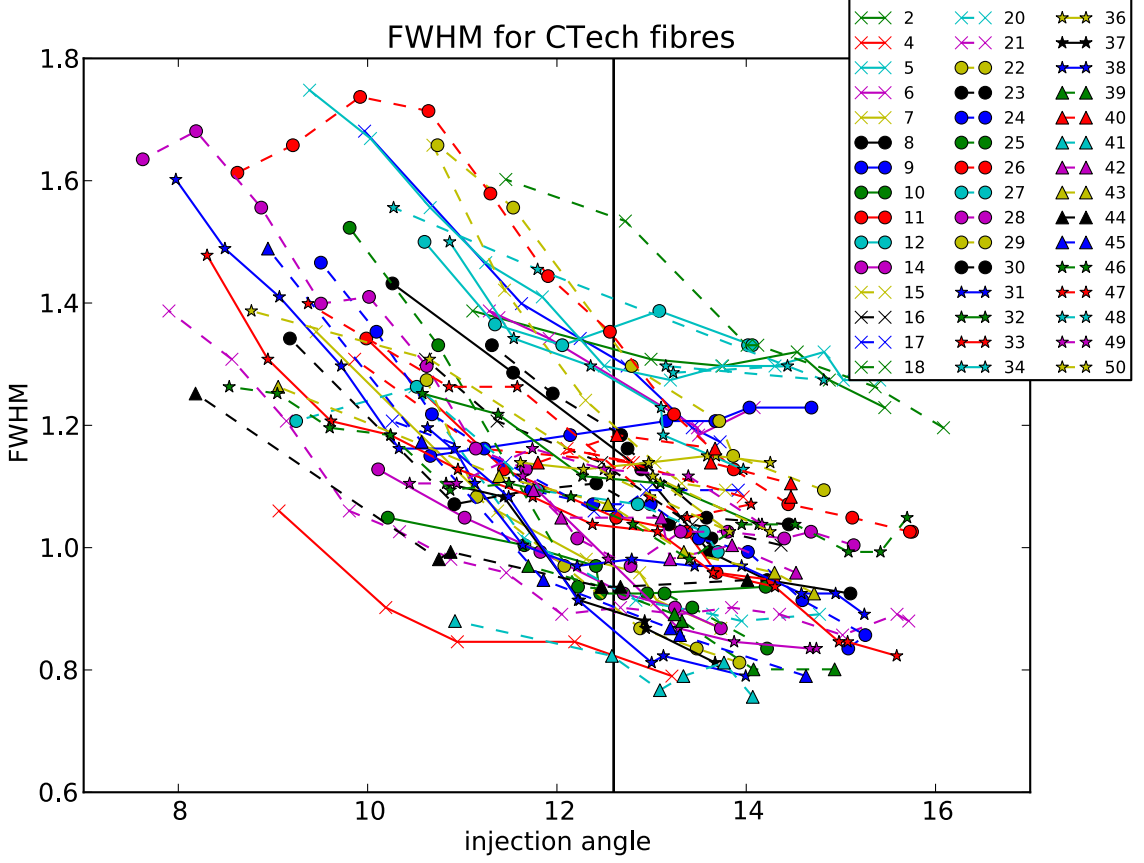
#### FRD Measure Repeatability

5 different fibers  
one each line  
measured 3 times

Fiber	Angle Avg	Ang sigma	FRD Avg	FRD Sigma
1	11.81	0.11	1.45	0.27
2	11.28	0.61	1.50	0.18
3	12.24	0.52	1.17	0.18
4	12.38	1.04	1.19	0.21
5	12.15	0.64	1.27	0.13
	11.97	0.59	1.31	0.19

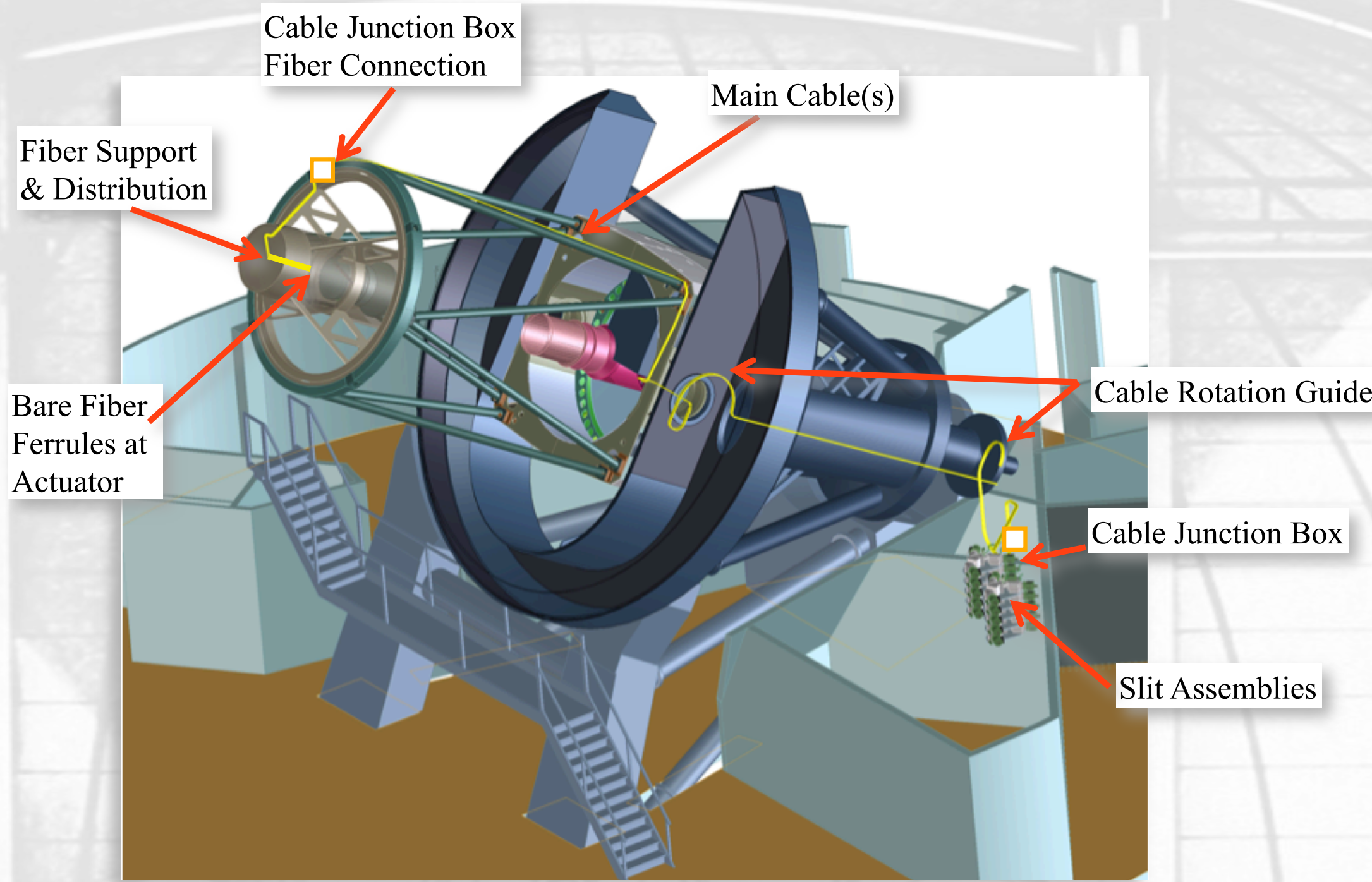
Average Deviation when Measuring a given Fiber's FRD

#### FRD vs input Angle

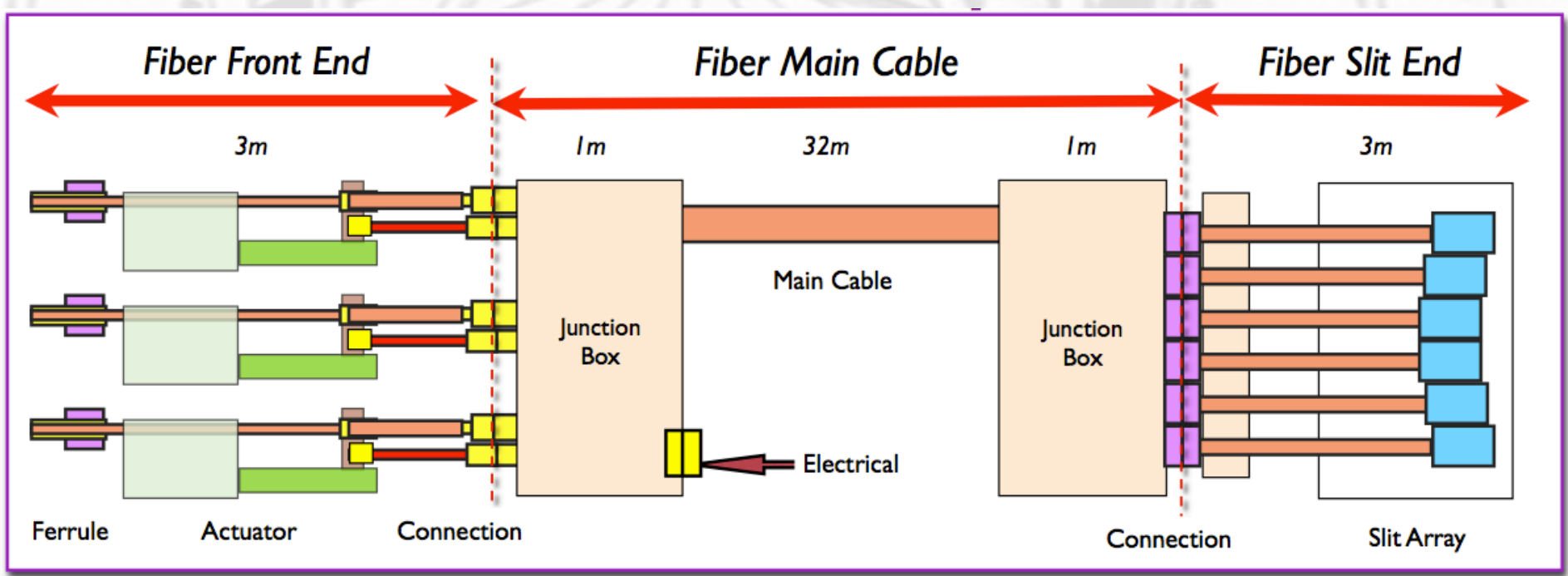


40m Fiber Far Field as a function of f/# including 3deg obscuration 100 um illumination, 625nm LED

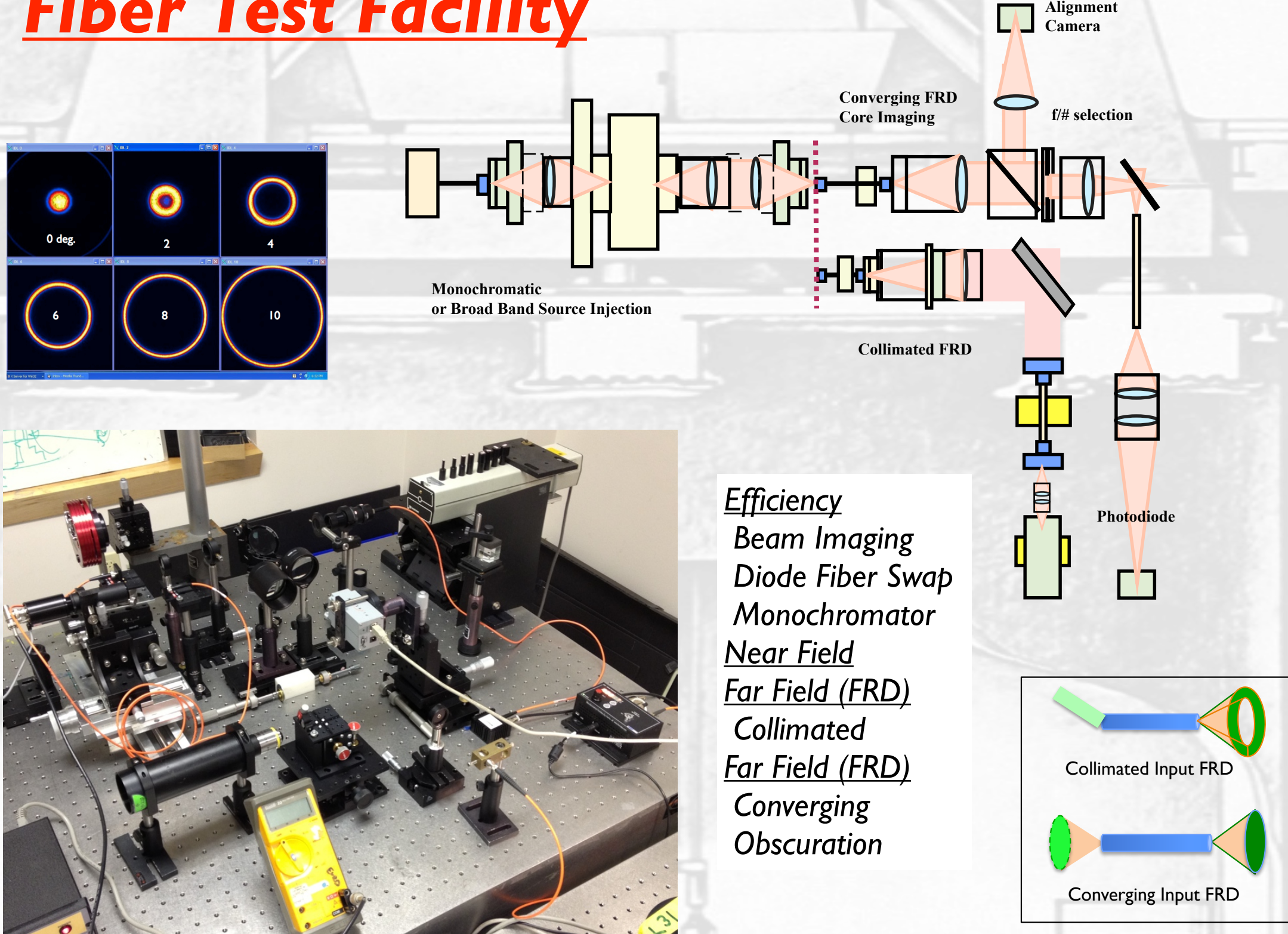
## FIBER SYSTEM CONCEPT



The main elements of the the BigBOSS fiber system are illustrated in place on the Mayall Telescope (above). A schematic diagram of the fiber system (below) shows the fiber front end that interfaces to the focal plane, the fiber main cable that traverses the facility, and the fiber slit end interfacing to the spectrographs.

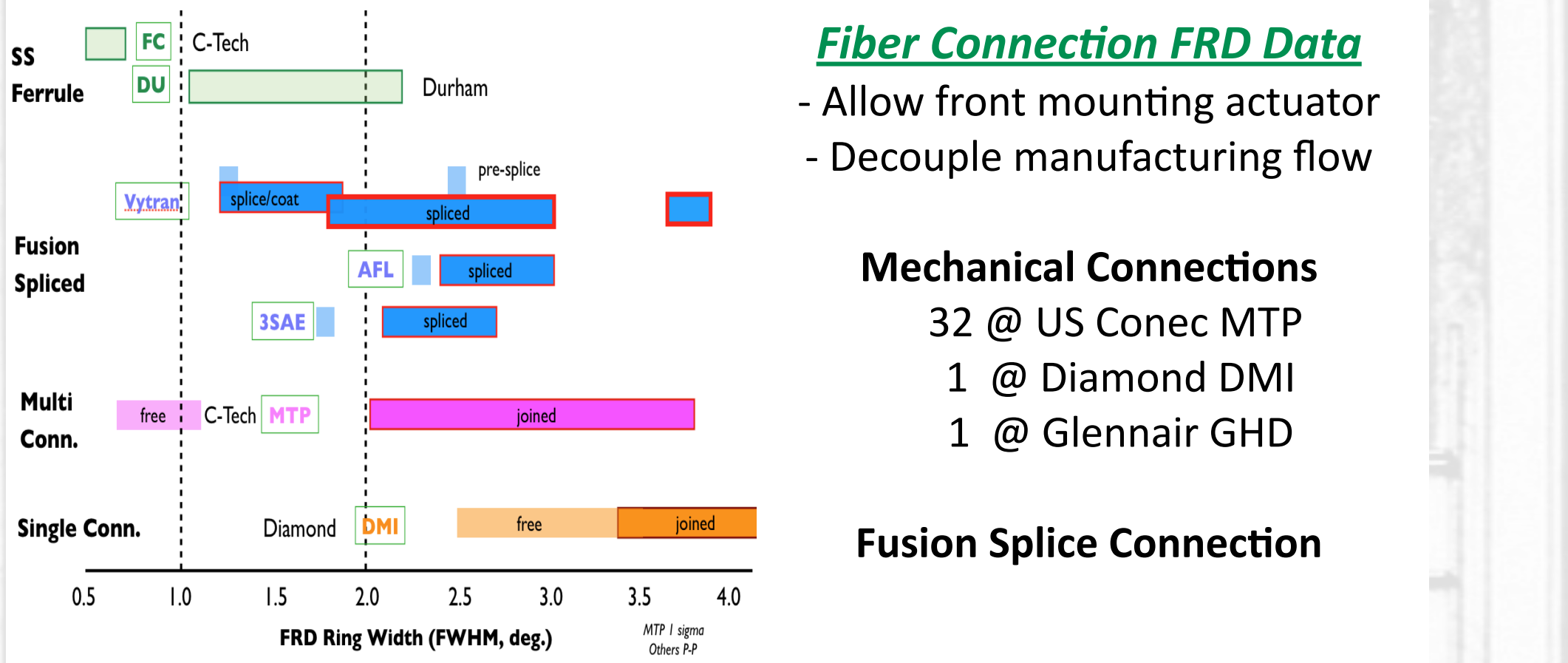


## Fiber Test Facility



A light source feeds a source fiber which illuminates a collimated or converging optic. The optics illuminate the fiber at a chosen input angle or f/#. An alignment camera views the fiber tip. The fiber output is viewed either in the far or near field with a camera or with a photodiode for throughput tests. Example data of collimated FRD observations are shown at a various input angles (degrees).

## Connection FRD Test Results



### Fiber Connection FRD Data

- Allow front mounting actuator
- Decouple manufacturing flow

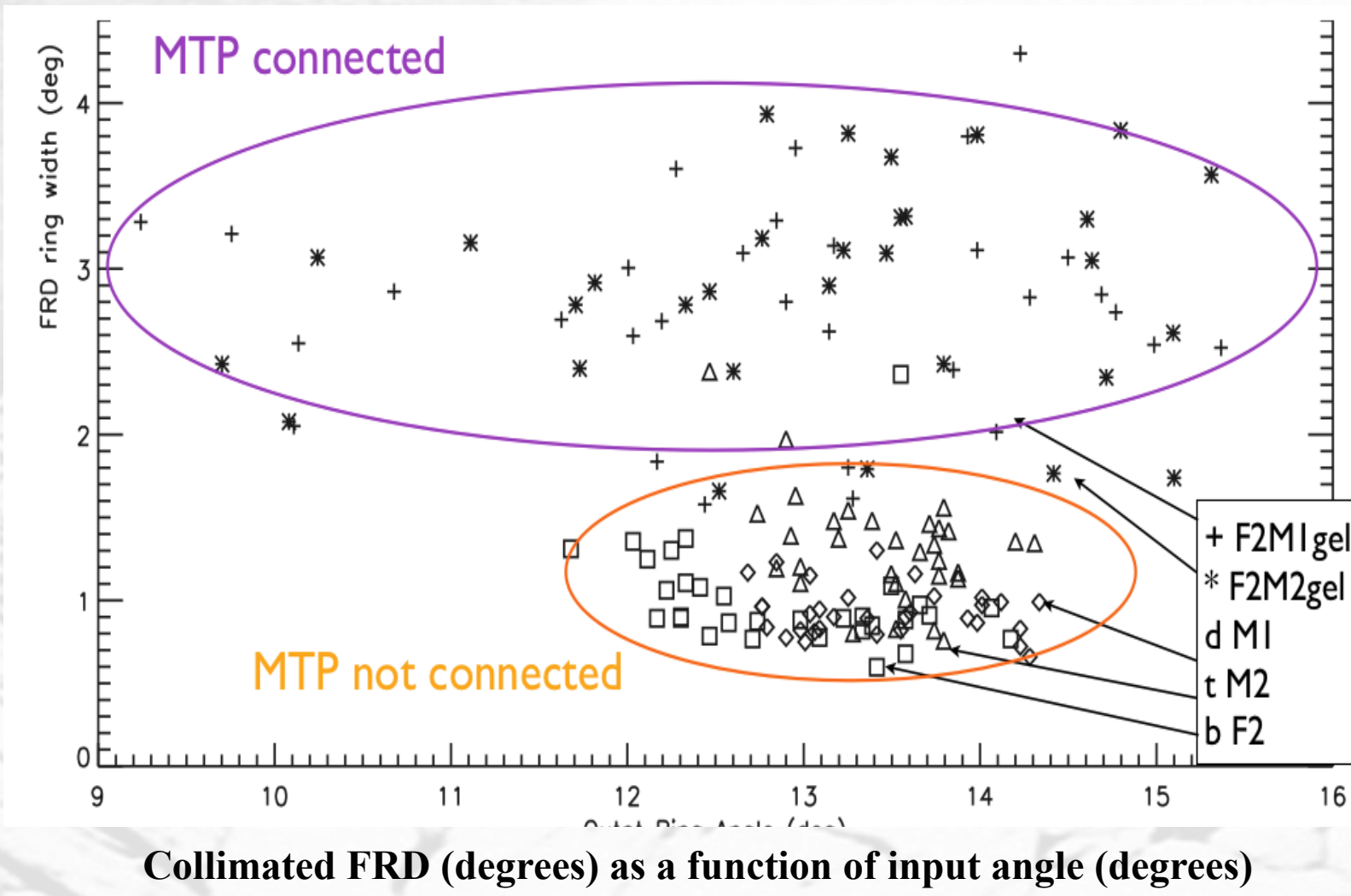
### Mechanical Connections

32 @ US Conec MTP  
1 @ Diamond DMI  
1 @ Glennair GHD

### Fusion Splice Connection

FRD testing results of mechanical fiber connectors and early tests of spliced fibers. Uncoupled fibers terminated with connection types are shown by open boxes. Fibers with connectors coupled is shown by the solid boxes. The boxes denote the full range of results. The GHD connector single ended FRD is too large to appear on the chart. See the lower right of this poster for the most recent splice connection test results.

### US Conec 32 x MTP Ferrule, finished by C-Tech



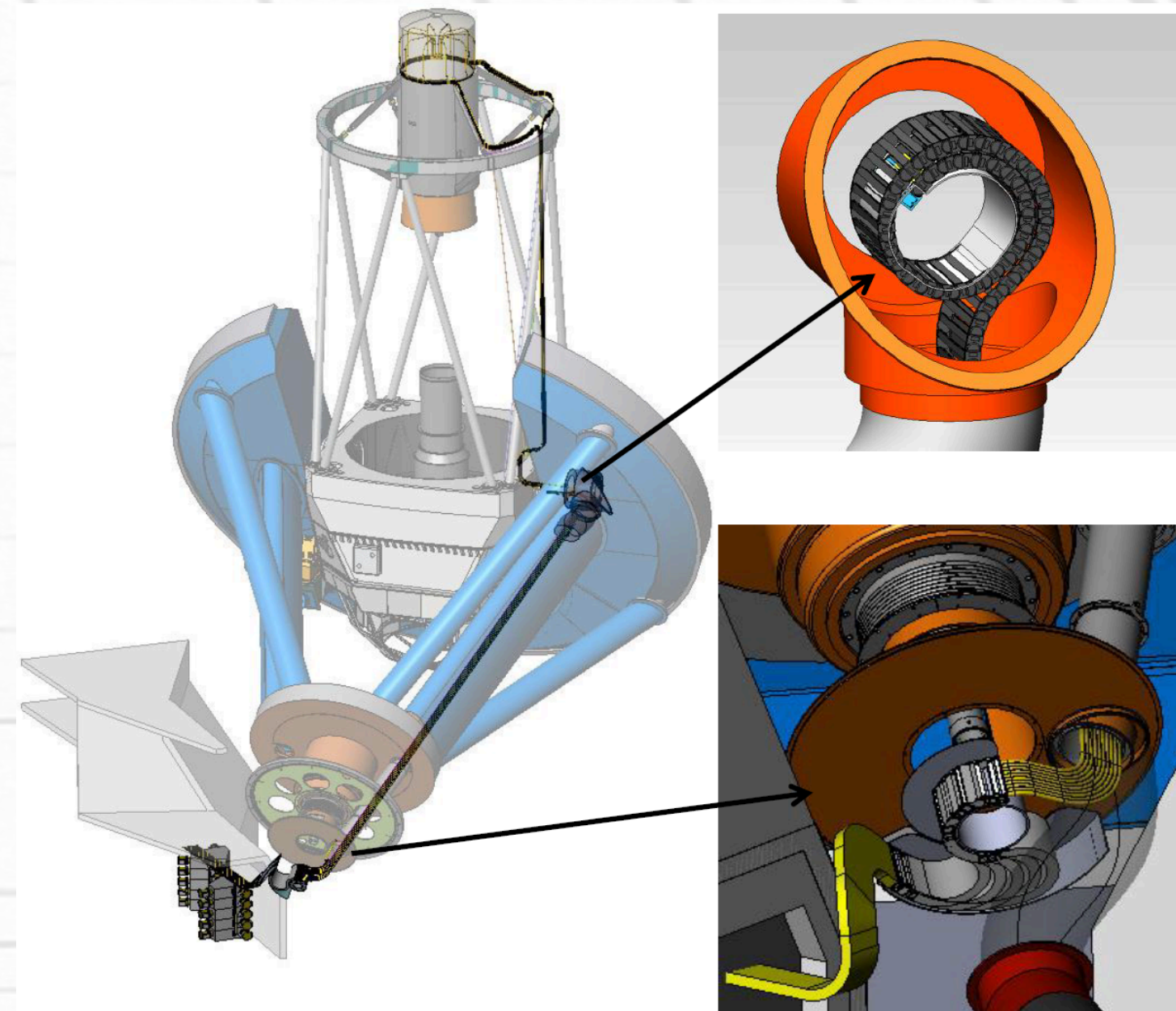
## Fiber Cable Routing



Fibers are gathered in groups of 32 from the focal plane

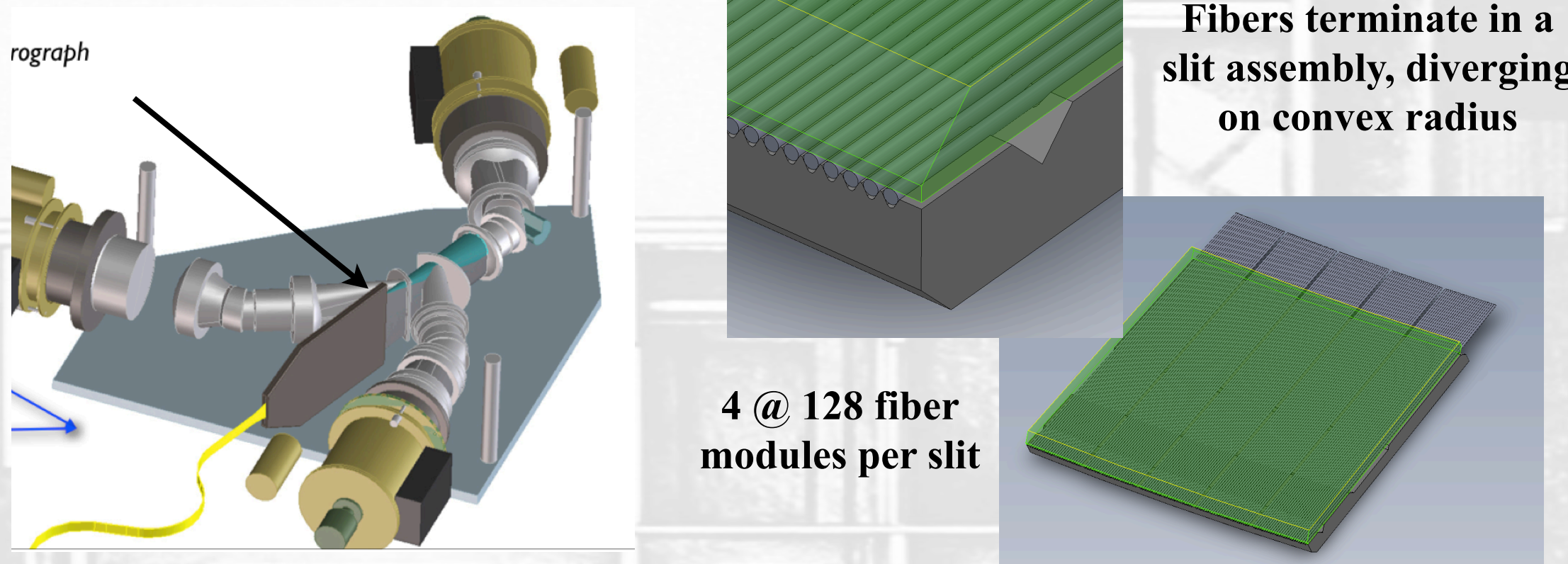
Fiber groups are routed to Junction Boxes behind the focal plane

## Cable Routing & Bending



Declination Axis (above) and Polar Axis (below) guide mechanisms maintain the 10 fiber cables in pure bending at the rotation points.

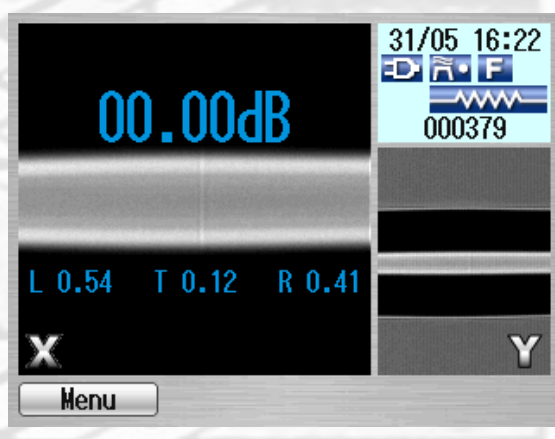
## Fiber Slit Assembly



Fibers terminate in a slit assembly, diverging on convex radius

4 @ 128 fiber modules per slit

## Fusion Splicing FRD Test Results

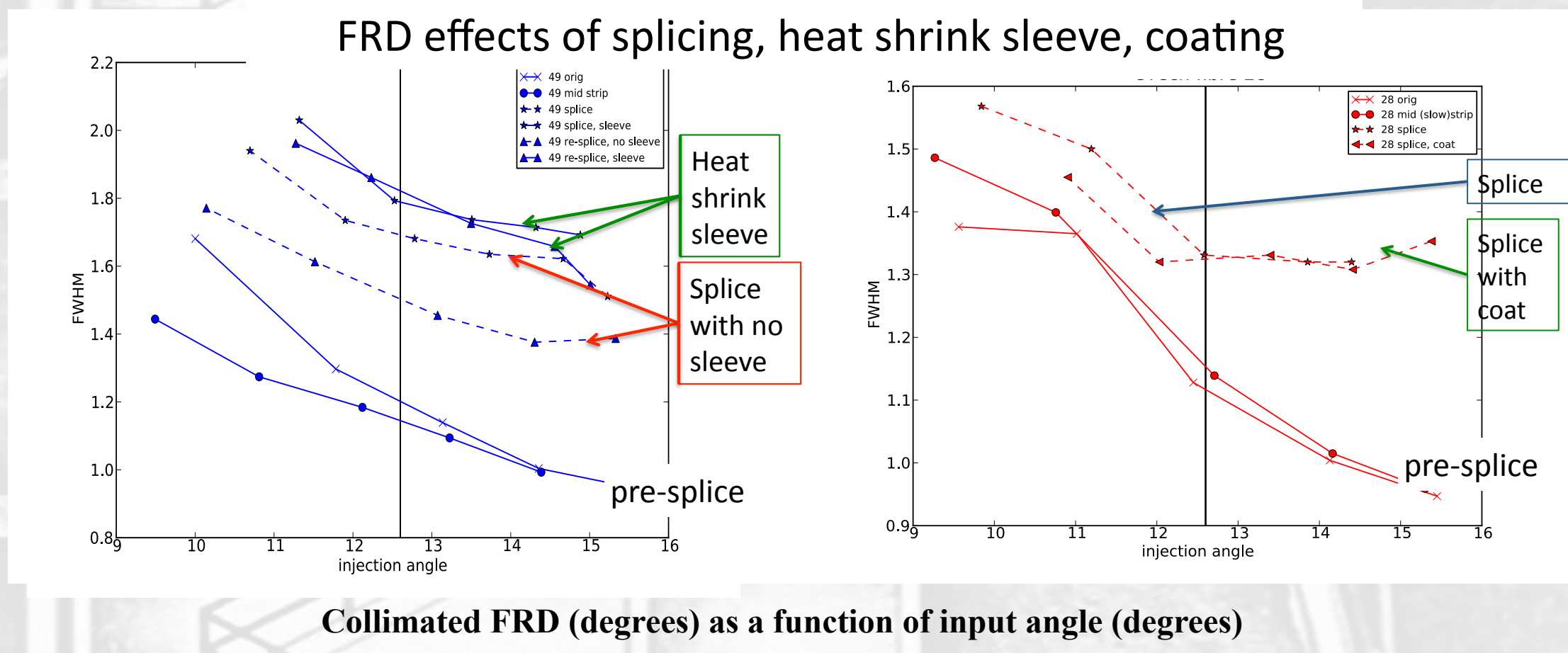


### Fiber Splicing Test Campaign

Field tests with vendors to optimize process parameters  
Explore cleaving, stripping, fusing & re-coating methods

120um core FBP fiber (Collimated FRD results)

- Fibers cleaved ends can deliver consistently FRD < 1.0 deg.
- Single splice fibers can consistently deliver FRD ~<1.6 deg
- Dual splice fibers can deliver FRD < 1.6 deg, but may have a more 'scattered' FRD profile
- Splice can deliver throughput loss < 1% per splice
- Acrylic recoating has no significant effect on FRD



Collimated FRD (degrees) as a function of input angle (degrees)

- Throughput losses in 2 m long test fibres were measured at a wavelength of 850 nm.
- Loss measurements were made relative to the fibre before it was cut and spliced back together
- Average losses for a single splice were around 0.6 %
- Average losses for two splices in series were < 1%

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